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PREDICTING TRANSMISSION TRANSFORMER CONDITION STATUS USING DGA SIGNATURES

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SUMMARY

This paper presents the results from a DGA study into failed Eskom Transmission transformers to identify typical failure signature patterns. Historical DGA data of failed units was analysed to identify typical signature patterns of the failures.

From the results it is clear that careful analysis of DGA patterns can predict dielectric, thermal and overloading problems. The methodology was developed by analyzing the DGA signatures and comparing the failure causes obtained after tear downs of the failed units.

For the cases that were analyzed the failure mode predicted using DGA signatures verified the findings after the tear downs. It is important to note that the DGA signatures gave clear indication of a fault in its early stages of development. The trends of the DGA signatures have proved to be a key component in the detection of faults.

KEYWORDS
Dissolved Gas Analysis
Thermal Failure Mode
Dielectric Failure Mode
Overheating Failure Mode

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INTRODUCTION

The current used DGA methods generally identify faults (abnormalities) prior to failure, which supports the idea of developing a prediction model. Furthermore, the classification of the faults (post failure) by the different methods is strongly correlated.

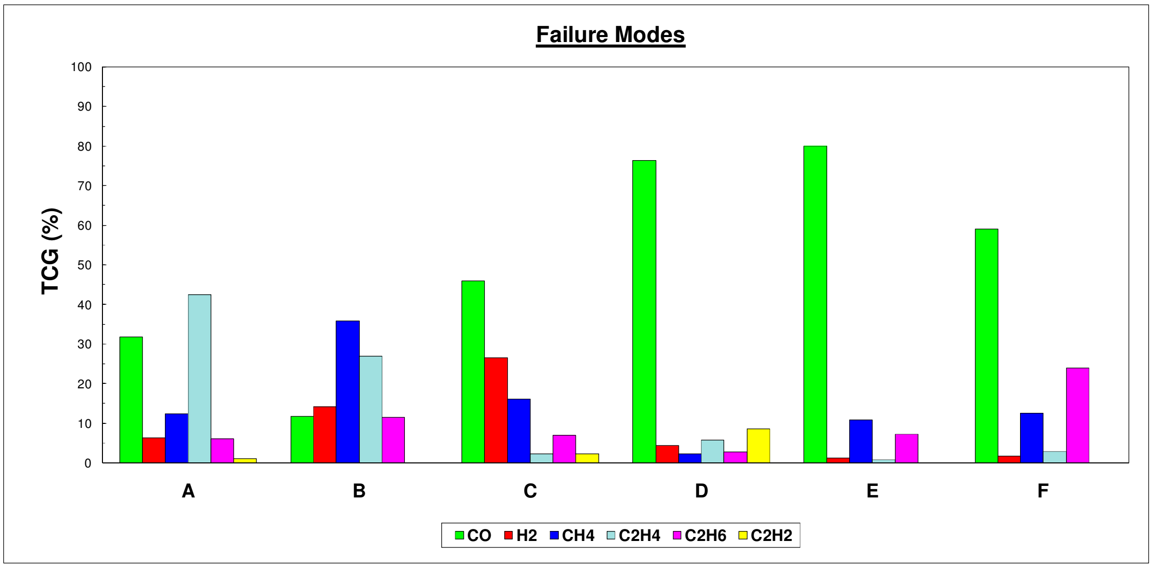
It has been shown that the historical DGA signatures, in general, can give early warning indicators of an imminent fault, the effects of a heavily loaded transformer, and the effects of intervention and the lack thereof. Furthermore, it can also be stated that many of the dielectric failures were initiated by thermal defects.

This study performed thus far documents the application of the existing DGA techniques on transformer oil condition data of failed transformers and determining their failure prediction success rate. The best fit solutions for the various transformer faults are provided. This work will aid in the development of DGA signatures to predict unhealthy/abnormal conditions or provide alerts for impending failures. The final research objective is to use transformer condition data to assess its current state and based on the results, the application of suitable interventions to manage the life of the transformer.

Fifty failed units for which the DGA signatures were compiled were compared to investigation reports made available from Eskom.

FAILURE MODES AND MECHANISMS

Historical DGA of failed units was performed to identify typical signature patterns of the failures. The DGA failure signatures were divided into 3 categories, namely dielectric, thermal and overloading/overloading. The trends of the DGA signatures proved to be a key component in the detection of these faults. Figure 1 shows the typical signatures of failure modes. Signatures **A** and **B** are thermal faults, Signatures **C** and **D** are dielectric faults and Signatures **E** and **F** are overheating/overloading faults.



Thermal Failure Mode

It can be seen that the dominant gases (Most prominent, as in position in relation to other gases), is typically ethylene and methane.

Dielectric Failure Mode
It can be seen that the dominant gases, is typically hydrogen and acetylene.

Overheating/Overloading Failure Mode
It can be seen that the dominant gases, is typically methane and ethane.

Furthermore, each of the above failure modes were then refined into the failure mechanisms listed below.

<u>Thermal Fault</u>
a) Circulating Current (Core and Earth (Tank), Core to Frame to Earth (Tank), Circulating current in windings)
b) Bad Connection with no cellulose involvement
c) Covered conductor

<u>Dielectric Fault</u>
a) Discharge
b) Arcing
c) Floating Potential

<u>Overheating/overloading Fault</u>
a) Overheating/Overloading
b) Severe Overheating/Overloading

The severity of the fault can be determined by placing the fault into 1 of the 3 stages (developing, developed or advanced). For example, for a circulating current type fault, the dominant gases shall be ethylene followed by significant levels of methane and ethane. If the fault is increasing in terms of severity the levels of hydrogen shall increase.

Fifty failed units for which the DGA signatures were compiled were compared to investigation reports made available from Eskom. Below are five such examples of which case studies shall be discussed below.

CASE STUDIES

1. Thermal Fault - Circulating Current

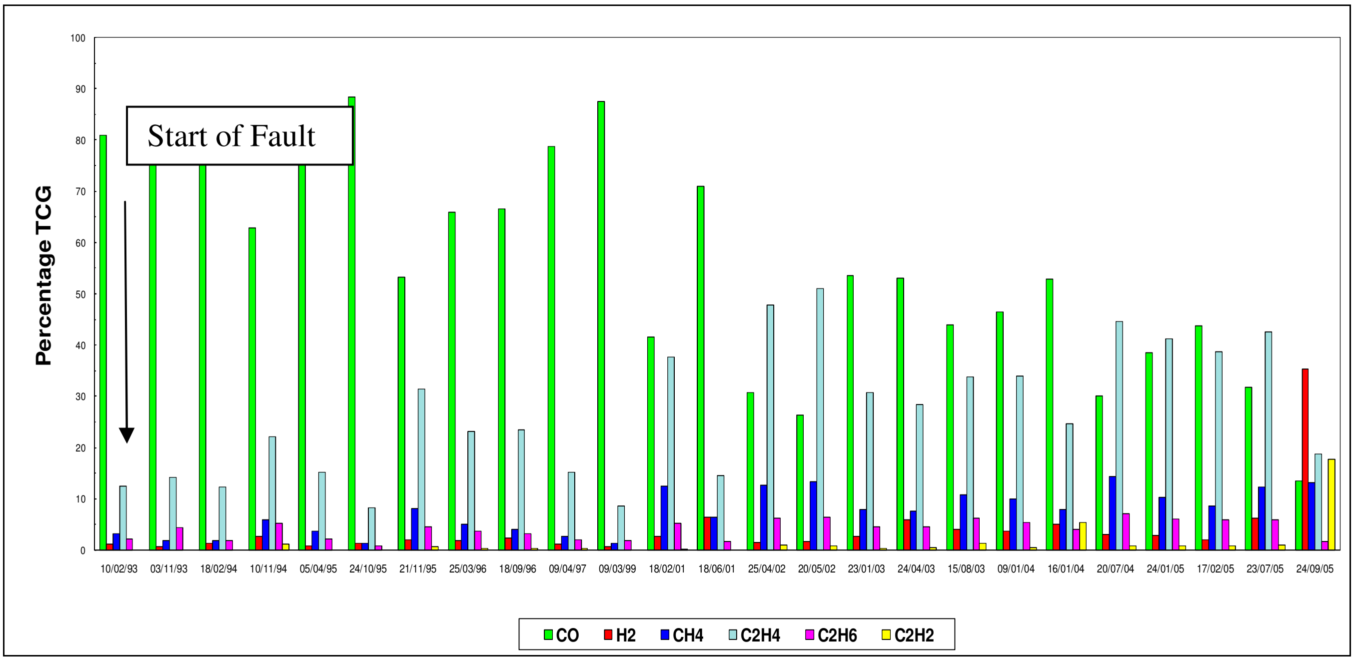


Figure 1: Historical DGA trend for transformer

Figure 1 gives the historical DGA signature. The failure mechanism was a core circulating current whose characteristic trend is high levels of ethylene followed by significant levels of methane and ethane. The DGA signature does not show a significant change over the history of the fault. The sample on the 10/02/93 (start of fault) was identified as a thermal failure mode. Intervention on this date may have prevented failure of the transformer. The severity of the fault is defined by increasing levels of hydrogen and acetylene. The failure sample is indicative of a dielectric type fault. This can be very misleading if the if the DGA signature is not analysed to identify the root cause of the fault.

2. Thermal - Windings Tracking Fault

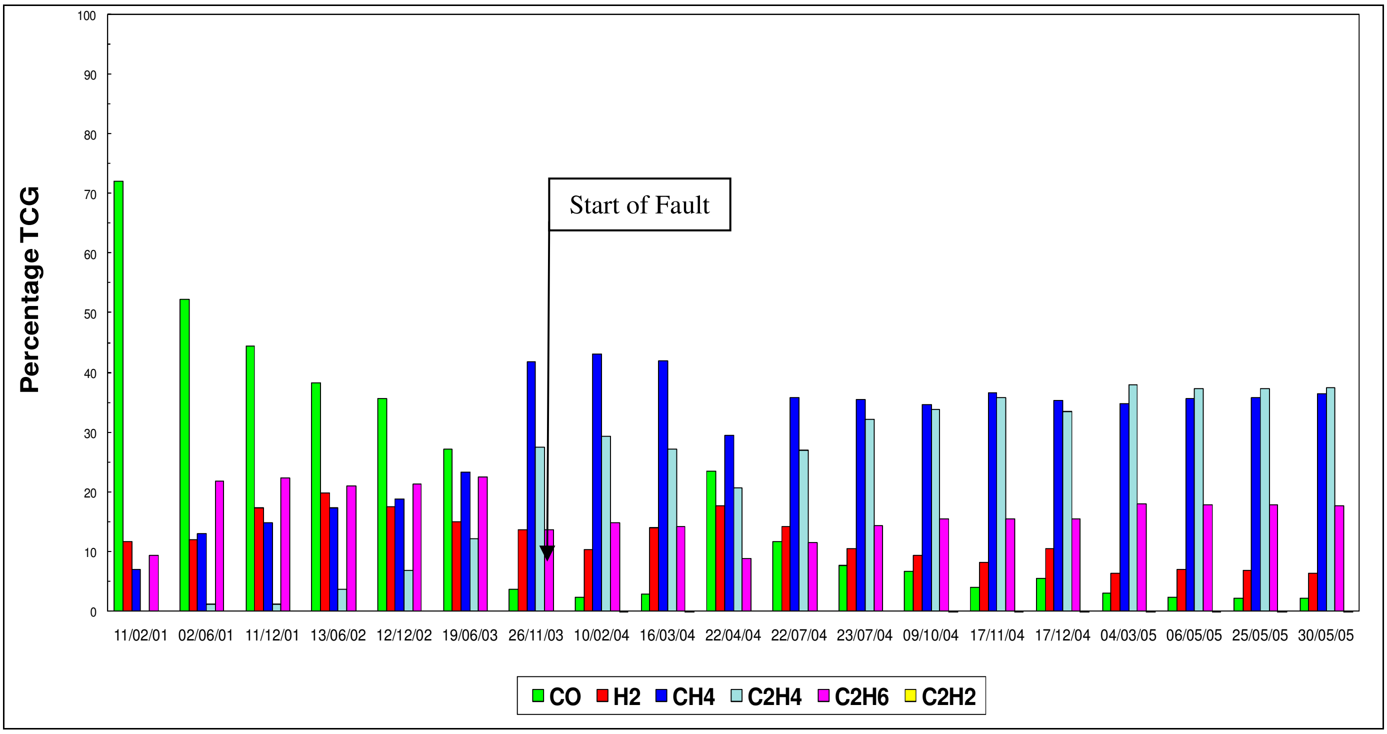


Figure 2: Historical DGA trend for transformer

Figure 2 gives the historical DGA signatures. The root cause for the failure was a thermal fault of the winding tracking type, which began on the 26/11/03, whose characteristic trend is ethylene and methane being the dominant gases. They are at similar levels and significantly high. A good indication of the severity of the fault is given by a decrease in carbon monoxide and an increase in ethylene and methane.

3. Dielectric - Discharge

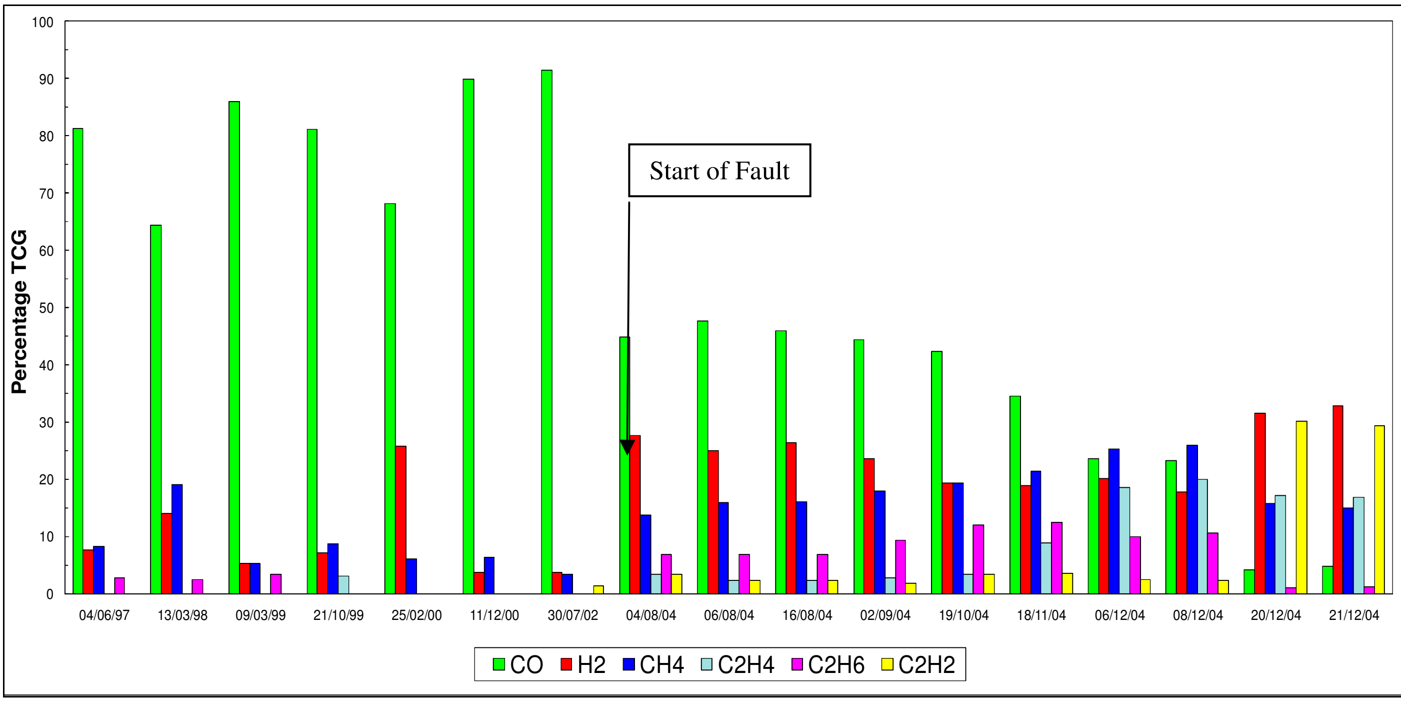


Figure 3: Historical DGA trend for transformer

Figure 3 gives the historical DGA signatures. The root cause for the failure was a discharge type fault. The fault began on the 04/08/04. The failure report indicated that it "failed due to tracking, causing a flashover to earth and damaging the windings of the C-phase". The characteristic trend is high levels of hydrogen followed by significant levels of methane. The severity of the fault is defined by increasing levels of methane. The fault sample is indicative of a dielectric type fault.

4. Overloading/Overheating - Severe

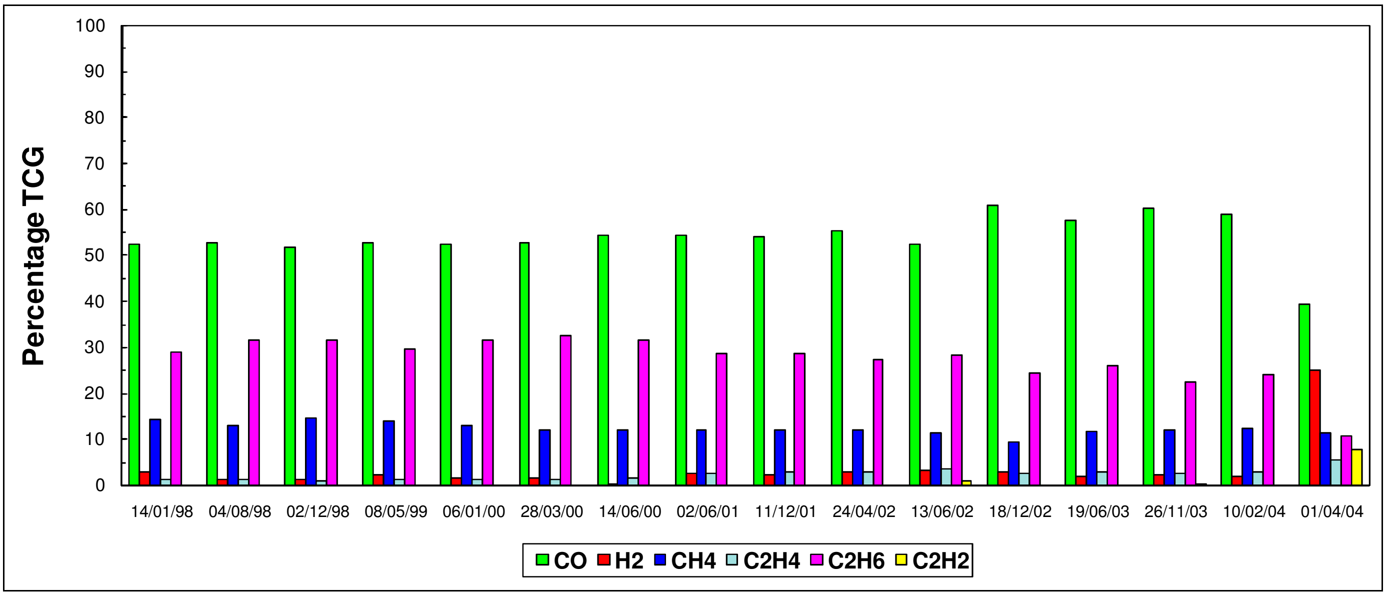


Figure 4: Historical DGA trend for transformer

Figure 4 gives the historical DGA signatures. The DGA signature does not show a significant change over the history of the fault. The root cause of the problem was an overheating/overloading fault, which existed throughout the DGA history. It was concluded that ethane leading methane is of a more severe problem than vice versa. This trend often leads to transformer failure. The total combustible gasses did give some indication of a fault.

STRAY GASSING

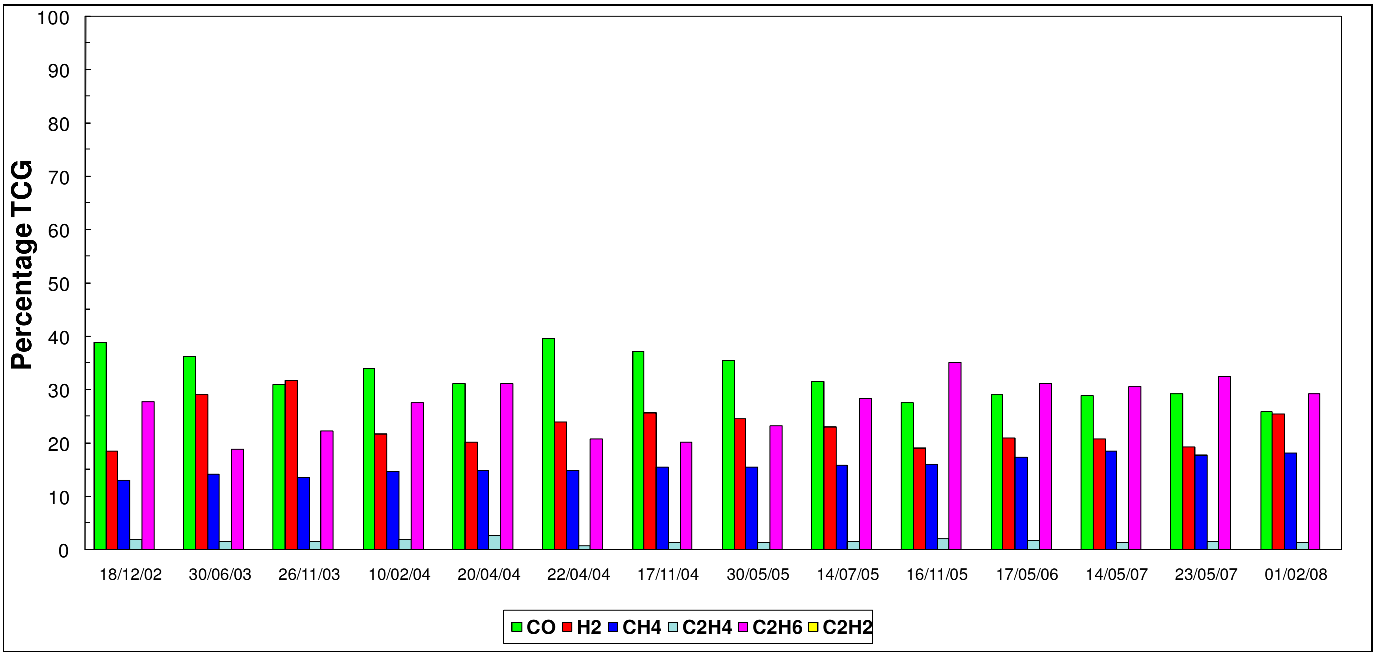


Figure 5: Historical DGA trend for transformer

Depending on the type of oil used, stray gassing may be mistaken as a discharge, overheating, and/or catalytic gassing on metal surfaces type of fault. It is therefore important to identify such gassing patterns and avoid misinterpreting stray gassing for a fault.

Figure 5 gives the historical DGA signatures. Stray gassing has a similar signature to that of an Overheating/Overloading DGA trend. The difference is the abnormal levels of hydrogen. The levels of hydrogen, methane and ethane are seen to fluctuate throughout the DGA history.

CONCLUSIONS

The following conclusions are relevant to the studies conducted:

The oil condition data of the failed transformers provided DGA signature trends of the various faults, namely: Circulating current, bad Connection with no cellulose involvement, Covered conductor, Discharge, Arcing, Floating Potential, Overheating/Overloading, Severe Overheating/Overloading and Stray Gassing. This confirms that historical DGA data of suspect transformers do contain information relating to imminent faults.

None of the existing DGA methods can identify stray gassing. The abnormal levels of hydrogen, methane and ethane known to stray gassing are evident.

For the population of failed transformers that were studied it was evident that given the DGA signatures prior to the fault, intervention could have been employed in order to prevent the failure. Now that the typical fault signatures have been discovered, early detection of faults (or developing faults) will lead to suitable intervention being carried timeously. Intervention (depending on the failure mode and mechanism) in the form of more regular oil sampling (and analysis), online testing (IR and PD scanning) and electrical testing can be done at an early stage thus preventing transformer failure.

The final research objective is to use develop an algorithm which shall use the transformer condition data to assess its current state and based on the results, the application of suitable interventions to manage the life of the transformer.

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